09/19/00 U.S. PTO

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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	AGLE0005
First Inventor or Application Identifier	Calderone et al.
Title	Increased Bandwidth in Aloha-Based Frequency Hopping
Express Mail Label No.	EL540885958US

jc658 U.S. PTO 09/664074 09/19/00

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231**

1. [X] * Fee Transmittal Form *(e.g., PTO/SB/17)* *(Submit an original and a duplicate for fee processing)*
2. [X] Specification [*Total Pages* 28] *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) *(35 U.S.C. 113)* [*Total Sheets* 4]
4. Oath or Declaration [*Total Pages* 2]
   - a. [X] Newly executed (original or copy)
   - b. [ ] Copy from a prior application (37 C.F.R. § 1.63(d)) *(for continuation/divisional with Box 16 completed)*
     - i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

** NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).*

5. [ ] Microfiche Computer Program *(Appendix)*
6. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   - a. [ ] Computer Readable Copy
   - b. [ ] Paper Copy (identical to computer copy)
   - c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [X] Assignment Papers (cover sheet & document(s))
8. [X] 37 C.F.R.§3.73(b) Statement *(when there is an assignee)* [X] Power of Attorney
9. [ ] English Translation Document *(if applicable)*
10. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
13. [X] * Small Entity Statement(s) *(PTO/SB/09-12)* [ ] Statement filed in prior application, Status still proper and desired
14. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
15. [ ] Other: .....

16. **If a CONTINUING APPLICATION,** *check appropriate box, and supply the requisite information below and in a preliminary amendment*

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No. _____/_____

Prior application information: Examiner _____ *Group / Art Unit:* _____

For CONTINUATION or DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

17. CORRESPONDENCE ADDRESS

[X] *Customer Number or Bar Code Label* 22862 *(Insert Customer No. or Attach bar code label here)* or [ ] *Correspondence address below*

Name					
Address					
City		*State*		*Zip Code*	
Country		*Telephone*		*Fax*	

Name (Print/Type)	Michael A. Glenn	*Registration No. (Attorney/Agent)*	30,176
Signature		*Date*	9/19/2000

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FEE TRANSMITTAL for FY 1999

Patent fees are subject to annual revision.
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TOTAL AMOUNT OF PAYMENT ($) 814.00

Complete if Known	
Application Number	Unassigned
Filing Date	Herewith
First Named Inventor	Calderone et al.
Examiner Name	Unassigned
Group / Art Unit	Unassigned
Attorney Docket No.	AGLE0005

METHOD OF PAYMENT (check one)

1. [X] The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number: 07-1445

Deposit Account Name: Michael Glenn

[X] Charge Any Additional Fee Required Under 37 CFR §§ 1.16 and 1.17

2. [ ] **Payment Enclosed:**
[ ] Check [ ] Money Order [ ] Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	760	201	380	Utility filing fee	345.00
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	760	208	380	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 345.00

2. EXTRA CLAIM FEES

		Extra Claims		Fee from below		Fee Paid
Total Claims	46	-20** = 26	X	9	=	234.00
Independent Claims	8	- 3** = 5	X	39	=	195.00
Multiple Dependent					=	

***or number previously paid, if greater; For Reissues, see below*

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim, if not paid
109	78	209	39	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($)429.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	380	216	190	Extension for reply within second month	
117	870	217	435	Extension for reply within third month	
118	1,360	218	680	Extension for reply within fourth month	
128	1,850	228	925	Extension for reply within fifth month	
119	300	219	150	Notice of Appeal	
120	300	220	150	Filing a brief in support of an appeal	
121	260	221	130	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,210	241	605	Petition to revive - unintentional	
142	1,210	242	605	Utility issue fee (or reissue)	
143	430	243	215	Design issue fee	
144	580	244	290	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	40.00
146	760	246	380	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	760	249	380	For each additional invention to be examined (37 CFR § 1.129(b))	

Other fee (specify) _____

Other fee (specify) _____

* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 40.00

SUBMITTED BY

Complete *(if applicable)*

Name (Print/Type)	Michael Glenn	Registration No. (Attorney/Agent)	30,176	Telephone	650-474-8400
Signature				Date	9/19/2000

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PTO/SB/10 (1-99)
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Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(c))--SMALL BUSINESS CONCERN

Docket Number (Optional) AGLE0005

Applicant, Patentee, or Identifier: Calderone et al.
Application or Patent No.: Unassigned
Filed or Issued: Herewith
Title: Increased Bandwidth in Aloha-Based Frequency Hopping Transmission Systems

I hereby state that I am
☐ the owner of the small business concern identified below:
☒ an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF SMALL BUSINESS CONCERN AgileTV Corporation

ADDRESS OF SMALL BUSINESS CONCERN 333 Ravenswood Avenue, Bldg. 202
Menlo Park, CA 94025

I hereby state that the above identified small business concern qualifies as a small business concern as defined in 13 CFR Part 121 for purposes of paying reduced fees to the United States Patent and Trademark Office. Questions related to size standards for a small business concern may be directed to: Small Business Administration, Size Standards Staff, 409 Third Street, SW, Washington, DC 20416.

I hereby state that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention described in:

☒ the specification filed herewith with title as listed above.
☐ the application identified above.
☐ the patent identified above.

If the rights held by the above identified small business concern are not exclusive, each individual, concern, or organization having rights in the invention must file separate statements as to their status as small entities, and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern, or organization having any rights in the invention is listed below:
☐ no such person, concern, or organization exists.
☒ each such person, concern, or organization is listed below.

Separate statements are required from each named person, concern or organization having rights to the invention stating their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

NAME OF PERSON SIGNING James E. Jervis

TITLE OF PERSON IF OTHER THAN OWNER Vice President of Intellectual Property

ADDRESS OF PERSON SIGNING 333 Ravenswood Ave. Menlo Park, CA 94025

SIGNATURE James E. Jervis DATE 9-18-00

Increased Bandwidth in Aloha-based Frequency Hopping Transmission Systems

BACKGROUND OF THE INVENTION

TECHNICAL FIELD

The invention relates to transmission systems. More particularly, the invention relates to a method and apparatus that provides increased bandwidth in Aloha-based frequency hopping transmission systems.

DESCRIPTION OF THE PRIOR ART

The installed base of cable television set-top boxes was designed for efficient downstream, *i.e.* cable plant to subscriber, information delivery. Upstream data transmission, *i.e.* from subscriber to cable plant, is much more restrictive, supporting only limited bandwidth. As new classes of interactive services become available, it becomes ever more important to increase the upstream transmission bandwidth. For example, if it is necessary to pass voice information from the subscriber to the cable headend (also known as the "headend"), sufficient upstream bandwidth must be made available.

One of the most popular digital set-top boxes, the General Instruments (now Motorola) DCT-2000, is a useful example. When the box was first deployed,

upstream transmissions were restricted to user pay-per-view requests, and other infrequent transmissions. As a consequence, the transmission format used for upstream transmissions was not required to be very efficient, and in fact, it is not very efficient.

In this set-top box, the transmit hardware is capable of selecting twenty different 256K bps channels, each of which uses QPSK transmission coding. While the hardware is capable of frequency-hopping to avoid channels which are subject to interference, the scheme used is fairly static, with typical deployments only using two active upstream communications channels, for an aggregate bandwidth of only 512K bps per cluster of set-top boxes. This cluster is called a node in cable television terms, and typically represents between 500 and 2000 subscribers.

Furthermore, the transmission control protocol used, referred to as Aloha, is one where an individual set-top box immediately transmits any pending request to the headend, without regard to whether or not the channel is already in use. This transmission is repeated at regular intervals until the box receives an acknowledgement command, indicating successful receipt of the transmission.

Downstream data transmission occurs in a separate frequency band from the upstream channels. As is well-understood, this transmission control protocol is quite inefficient due to the number of collisions which ensue, *e.g.* simultaneous transmissions from different set-top boxes which interfere with one another, forcing all of the transmitters to repeat their transmissions again. This leads to

typical channel utilization on the order of just 30%. As a consequence, the total bandwidth available for upstream transmission per node is only about 30% * 512K bps = ~137K bps, on average.

Transporting voice across this limited bandwidth is not practical because an individual voice stream requires a minimum of perhaps 4K bps, meaning that at most (137K / 4K =) 34 people could use the link simultaneously, which is as little as (34 / 2000 =) 1.7% of the available households.

It would be advantageous to provide a method and apparatus that increases bandwidth in Aloha-based frequency hopping transmission systems, for example, thereby allowing voice transmission in such systems.

SUMMARY OF THE INVENTION

The preferred embodiment of the invention provides a method and apparatus that increases bandwidth in Aloha-based frequency hopping transmission systems, for example, thereby allowing voice transmission in such systems.

A first step in improving efficiency of known systems is to increase the number of parallel upstream transmissions by changing known systems from frequency hopping to a parallel transmission model. To increase upstream bandwidth, the invention replaces the existing headend receiver with one that is capable of simultaneously receiving data from all of the possible upstream channels simultaneously.

Next, by treating the head-end receiver and the set-top boxes as an integrated system, it is possible to use the existing transmission spectrum much more efficiently. Instead of enabling each set-top box to perform frequency hopping, it is much more effective if the head-end receiver is made responsible for active frequency management of the upstream transmission spectrum. To do this, when the system is first powered-up, the head-end receiver examines the RF spectrum to determine which frequencies are available, and which are not available due to interference from other sources. After determining which frequencies are free of interference, the headend receiver then polls the node to determine how many set-top boxes are active in this node. Once this is complete, the headend receiver partitions the total number of set-top boxes into an approximately equal number of set-top boxes for each of the available upstream data channels. That is, the boxes are assigned a transmission channel. The head-end receiver then commands each set-top box to tune to the channel it has been assigned by sending the channel selection information to each set-top box, *i.e.* using the separate downstream transmission channel mentioned above.

A second major change to known systems revises the transmission control protocol from an Aloha system to a slotted assignment system. To do this, the head-end receiver is used not just to assign each set-top box a specific transmission channel, but also a specific transmission time slot. By assigning a specific set-top box to a particular slot, it becomes possible for multiple set-top

boxes to transmit in sequential slots, while assuring that the transmission packets do not collide.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a system architecture according to the invention;

Fig. 2 is a flow diagram showing a channel assignment scheme according to the invention;

Fig. 3 shows channel and status information and corresponding allocation table entries according to the invention;

Fig. 4 is a timing diagram showing slot assignments according to the invention; and

Fig. 5 shows is a flow diagram that the provision of high resolution slot interrupts in a low resolution device.

DETAILED DESCRIPTION OF THE INVENTION

The preferred embodiment of the invention provides a method and apparatus that increases bandwidth in Aloha-based frequency hopping transmission systems thereby allowing, for example, voice transmission in such systems.

Fig. 1 is a block diagram of a system architecture according to the invention. Such systems with which the invention may be used can include, but are not

limited to, a headend receiver 10 and one or more set-top boxes 11, 12 between which communication proceeds over a plurality of communications channels, *e.g.* $Channel_1$-$Channel_N$.

Hopping-Parallel Transmission

A first step in improving efficiency of known systems is to increase the number of parallel upstream transmissions. To do this, the nature of the transmission system must be revised. However, replacing existing set-top boxes is a very expensive proposition, so it is extremely desirable to devise a method of accomplishing this task using existing set-top boxes. The invention achieves this goal by changing such systems from frequency hopping to a parallel transmission model.

To increase upstream bandwidth, the first step is to replace the existing headend receiver with one that is capable of simultaneously receiving data from all of the possible upstream channels simultaneously, *i.e.* twenty in the case of the DTC-2000 discussed above.

Next, by treating the head-end receiver and the set-top boxes as an integrated system, it is possible to use the existing transmission spectrum much more efficiently. Fig. 2 is a flow diagram showing a channel assignment scheme according to the invention

Instead of enabling each set-top box to perform frequency hopping, it is much more effective if the head-end receiver is made responsible for active frequency management of the upstream transmission spectrum. To do this, when the system is first powered-up (100) and intermittently thereafter, the head-end receiver examines the RF spectrum to determine which frequencies are available (101), and which are not available due to interference from other sources. After determining which frequencies are free of interference, the headend receiver then polls the node to determine how many set-top boxes are active in this node (102). Once this is determined, the headend receiver partitions the set-top boxes into an approximately equal number of set-top boxes for each of the available upstream data channels (103). That is, the boxes are assigned a transmission channel. The head-end receiver then commands each set-top box to tune to the channel it has been assigned by sending the channel selection information to each set-top box (104), *i.e.* using the separate downstream transmission channel mentioned above.

The headend receiver uses an allocation table 14 (Figs. 1 and 3) to keep track of the assignments of channels by storing a mapping between each channel and the set-top box to which the channel is assigned. An important element of the allocation table is that it keeps track of areas which are deemed to be busy. Thus, a key function of a headend receiver is in finding those frequencies which are not available, and eliminating them from the allocation table.

One reason for using frequency hopping is that it is relatively insensitive to interference by virtue of the fact that if there is an interfering carrier, such carrier only interferes with one step of the frequency hopping sequence. Therefore, only a minimal amount of information is lost and an error correction scheme can usually correct for this loss.

In the preferred embodiment of the invention, if there is interference on a channel, *e.g.* the channel is busy, then the channel is removed from the allocation table and is not allocated to any set-top box until it is no longer busy. Thus, the invention actively avoids interference instead of passively correcting for or responding to such interference because busy channels are actually removed from the allocation table. When there is a need to assign a channel to a set-top box, the headend receiver only sees the available channels, as listed in the allocation table. When a busy channel becomes free, it is put back into the allocation table and can subsequently be assigned by the headend receiver.

By making this simple change, the number of upstream channels increases dramatically, from typically two upstream channels, to perhaps sixteen channels depending on the amount of interference which is actually present in the upstream transmission spectrum. In the case mentioned above, this provides eight times more upstream transmission bandwidth, allowing up to (1.7% * 8) = 13.6% of households to transmit voice information simultaneously.

Improving Channel Utilization

A second major change to known systems requires no hardware whatsoever, but revises the transmission control protocol from an Aloha system to a slotted assignment system. To do this, the head-end receiver is used not just to assign each set-top box a specific transmission channel, but also a specific transmission time slot (105; see Fig. 2).

For the purposes of this document, a "slot" (see Fig. 4) is a specific slice of time used to transmit information, typically a fraction of a second in length. Here, assume that each second on each channel is divided up into one thousand slots, for a slot length of one millisecond. By assigning a specific set-top box to a particular slot, which is stored in a time slot table 16 (see Fig. 1), it becomes possible for multiple set-top boxes to transmit in sequential slots, while assuring that the transmission packets do not collide.

It is known in time division multiple access systems which of many transmitters is allowed to transmit in a given time slot. One such method is referred to as a reservation protocol in which a talker who wants to talk requests, and is then assigned, one of the available time slots. When that time slot arrives, the talker talks, and then is quiet while others talk. The management and assignment of time slots comes from some central authority, which in the case of a cable modem system is the headend controller. A reserved time slot allows a modem to transmit a known amount of information in a known period. However, if the

modem does not wish to use the time slot, the time slot is not available for use by anyone else until the controller decides that the time slot is available and then assigns it to someone else. (see W. Ciciora, J. Farmer, D. Large, Modern Cable Television Technology, Ch. 4, pp. 199, Morgan Kaufman Publishers, Inc., San Francisco, (1999).

One general problem in known systems is that the assignment of slots normally requires very precise alignment of the timing of each device in the system, such that each transmitter knows precisely when its assigned slot time arrives.

One known technique is to define a guard band such that a worst case clock skew between different transmitters does not result in overlap from slot to slot. This guard band itself often requires a substantial protion of the bandwidth that is available. There are a number of factors that go into computing the optimal guard band, such as local oscillator inaccuracy multiplied by the duration of time between time synchronization, and uncertainty involved in the hardware transmission path, *i.e.* variation in latency between the various set top boxes for which it is difficult, if not impossible, to account.

The presently preferred method of assigning slots in the system herein is for the downstream data transmitter to broadcast a timestamp at a regular interval 106), *e.g.* every one second. This heartbeat is received by all set-top boxes in the network, forming a rigid timing standard for the boxes. By repeating the heartbeat at regular, *e.g.* one second, intervals the inherent timing inaccuracy of

the individual set-top boxes is not given the opportunity to become significant because each box resets its slot timers when it receives the broadcast time-stamp (114). In this manner, a consistent time is maintained throughout the network.

However, an additional problem arises in known cable systems. Because each of the set-top boxes may be at very different distances from the headend, and because each may have a different internal processing speed, the response time from the different set-top boxes is individually skewed, thereby preventing perfect alignment of the different transmission slots. To correct for this, the headend receiver requests that each individual set-top box echo a specific command (108) as rapidly as possible during system initialization (107), while polling the node for attached set-top boxes. At the instant the head-end receiver sends out the command, it begins running an internal timer (17; see Fig. 1). This timer is incremented (110) until a response is received from the set-top box (109). This response may be an echo of the timestamp. The value of the timer once the response has been received is an accurate measure of the propagation delay in the network, plus the processing delay in the particular set-top box. By applying this new knowledge, it becomes possible to align the timing for all set-top boxes in the system (111), so that the slot times are aligned.

Note that a timestamp is used to account for varying delays in downstream transmission. The timestamp which is transmitted contains a value indicating the actual moment in time when the transmitted packet hits the wire. By having the

set-top box echo the received timestamp, it becomes possible to measure the precise time overhead or loss inherent in the network and the particular set-top box, even in the presence of varying transmit delay in the downstream transmitter. Note that maximal accuracy may be obtained by repeating this process several times and averaging the time correction results.

To accomplish slot alignment, the head-end receiver transmits the time correction factor it computed while polling the set-top box back to the set-top box (112). Inside the set-top box, this timing correction factor is subtracted from the nominal slot time to find a corrected slot time (113). By doing so, the set-top box's processing time effectively becomes zero. As a consequence, by the time the set-top box actually begins transmission, its packet is aligned properly to the desired slot transmission point so that sequential transmissions do not interfere with one another.

As a final step, many set-top boxes do not have the hardware clock resolution to enable interrupts to occur at the desired slot frequency. To resolve this, a combination of interrupts and software counters are used to provide finer time granularity. Fig. 5 shows is a flow diagram that shows the provision of high resolution slot interrupts in a low resolution device. In essence, a hardware timer interrupt 17 (Fig. 1) is programmed to awaken the CPU at the set-top box at the nearest hardware interrupt point preceding the desired slot interval (150, 151), then software counters 18 are used to count down the remaining time (152) until this set-top box's transmission slot (153, 154). By combining these methods, it

becomes possible to have more slots available than the hardware interrupt would otherwise make possible because the slots may be subdivided into sub-slots that are finer than the resolution of the set-top box.

All told, this slotted approach to transmission can increase utilization of individual upstream channels from approximately 30%, to in excess of 80%. As a consequence, the number of simultaneous voice transmissions in the example system described here increases to (13.6% * 80% / 30%) = 36%, *i.e.* more than twenty times faster than the original installation. This substantial bandwidth increase is crucial because it enables entirely new classes of service to be delivered to subscriber's homes, without requiring expensive replacement of the installed base of set-top boxes.

Although the invention is described herein with reference to the preferred embodiment, one skilled in the art will readily appreciate that other applications may be substituted for those set forth herein without departing from the spirit and scope of the present invention. Accordingly, the invention should only be limited by the Claims included below.

CLAIMS

1. An apparatus for increasing bandwidth in a frequency hopping transmission system, comprising:

a headend receiver responsible for active frequency management of an upstream transmission RF spectrum, wherein said headend receiver is capable of simultaneously receiving data from all possible upstream channels; and

one or more set-top boxes, each of said set top boxes being associated with a particular one of one or more nodes;

wherein communication between said headend receiver and said one or more set-top boxes proceeds via a parallel transmission model over said RF spectrum which comprises a plurality of communications channels.

2. The apparatus of Claim 1, wherein when said apparatus is first powered-up and optionally intermittently thereafter, said head-end receiver periodically examines said RF spectrum to determine which frequencies are available, and which are not available due to interference from other sources.

3. The apparatus of Claim 2, wherein said headend receiver polls said one or more nodes to determine how many of said one or more set-top boxes are active in each node after determining which frequencies are free of interference.

4. The apparatus of Claim 3, wherein said one or more set-top boxes are each assigned to a transmission channel by said headend receiver.

5. The apparatus of Claim 4, wherein said headend receiver partitions said one or more set-top boxes into an approximately equal number of set-top boxes for each of said available upstream data channels

6. The apparatus of Claim 4, wherein said head-end receiver commands each of said one or more set-top boxes to tune to a channel to which it has been assigned by sending channel selection information to each of said one or more set-top boxes.

7. The apparatus of Claim 6, wherein said headend receiver uses a separate downstream transmission channel to send channel selection information to each of said one or more set-top boxes.

8. The apparatus of Claim 4, wherein headend receiver further comprises:

an allocation table for keeping track of assignments of channels by storing a mapping between each channel and a set-top box to which said channel is assigned.

9. The apparatus of Claim 8, wherein said allocation table keeps track of areas which are deemed to be busy.

10. The apparatus of Claim 8, wherein said headend receiver finds those frequencies which are not available and eliminates them temporarily from said allocation table.

11. The apparatus of Claim 1, wherein said headend receiver further comprises:

a slotted assignment system which assigns each of said one or more set-tops boxes a specific transmission slot, wherein each slot comprises a specific slice of time used to transmit information.

12. The apparatus of Claim 11, said slotted assignment system further comprising:

a guard band such that a worst case clock skew between different transmitters does not result in overlap from slot to slot.

13. The apparatus of Claim 11, said slotted assignment system further comprising:

a timestamp that is broadcast downstream to each of said one or more set-top boxes at a regular interval.

14. The apparatus of Claim 13, wherein said timestamp is repeated at regular intervals so that inherent timing inaccuracy of individual set-top boxes is not given an opportunity to become significant because each of said one or more set-top boxes resets a slot timer when it receives a broadcast time-stamp.

15. The apparatus of Claim 13, wherein said headend receiver requests that each of said one or more set-top boxes echos a specific command as rapidly as

possible periodically, while polling each of said one or more nodes for attached set-top boxes.

16. The apparatus of Claim 15, wherein said headend receiver further comprises:

a mechanism that begins running an internal timer at the instant said head-end receiver sends out said command to a particular one of said one or more set-top boxes;

wherein said timer is incremented until a response is received from said particular one of said one or more set-top boxes;

wherein said response is an echo of said timestamp;

wherein a value of said timer is an accurate measure of propagation delay plus processing delay in said particular one of said one or more set-top boxes once a response has been received by said headend receiver; and

wherein a value is generated for each of said one or more set-top boxes to align timing for said one or more set-top boxes.

17. The apparatus of Claim 16, wherein said headend receiver repeatedly operates said mechanism several times and averages time correction results obtained thereby.

18. The apparatus of Claim 16, wherein said head-end receiver transmits a particular time correction factor it computed while polling said one or more set-top boxes back to a corresponding one of said one or more set-top boxes;

wherein said corresponding one or said one or more set-top boxes subtracts said timing correction factor from a nominal slot time to determine a corrected slot time; and

wherein a transmission packet is aligned properly to a desired slot transmission point by the time said particular one or said one or more set-top boxes actually begins transmission.

19. The apparatus of Claim 12, said slotted assignment system further comprising:

a mechanism that enables interrupts to occur at a desired slot frequency.

20. The apparatus of Claim 19, said mechanism comprising:

a timer interrupt programmed to awaken a CPU at each set-top box at a nearest hardware interrupt point preceding a desired slot interval; and

a counter for counting down a remaining time until said set-top box's transmission slot is reached;

wherein said slots are subdivided into sub-slots that are finer than the timing resolution of said set-top box.

21. A method for increasing bandwidth in a frequency hopping transmission system, comprising the steps of:

providing a headend receiver responsible for active frequency management of an upstream transmission RF spectrum, wherein said headend receiver is capable of simultaneously receiving data from all possible upstream channels; and

providing one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes;

wherein communication between said headend receiver and said one or more set-top boxes proceeds via a parallel transmission model over said RF spectrum which comprises a plurality of communications channels.

22. The method of Claim 21, further comprising the step of:

said head-end receiver examining said RF spectrum to determine which frequencies are available, and which are not available due to interference from other sources.

23. The method of Claim 22, further comprising the step of:

said headend receiver polling said one or more nodes to determine how many of said one or more set-top boxes are active in each node after determining which frequencies are free of interference.

24. The method of Claim 23, further comprising the step of:

said headend receiver assigning each of said one or more set-top boxes to a transmission channel.

25. The method of Claim 24, further comprising the step of:

said headend receiver partitioning said one or more set-top boxes into an approximately equal number of set-top boxes for each of said available upstream data channels

26. The method of Claim 24, further comprising the step of:

said head-end receiver commanding each of said one or more set-top boxes to tune to a channel to which it has been assigned by sending channel selection information to each of said one or more set-top boxes.

27. The method of Claim 26, further comprising the step of:

said headend receiver using a separate downstream transmission channel to send channel selection information to each of said one or more set-top boxes.

28. The method of Claim 24, further comprising the step of:

keeping track of assignments of channels by storing a mapping between each channel and a set-top box to which said channel is assigned in an allocation table associated with said headend receiver.

29. The method of Claim 28, further comprising the step of:

said allocation table keeping track of areas which are deemed to be busy.

30. The method of Claim 28, further comprising the step of:

said headend receiver finding those frequencies which are not available and eliminates them from said allocation table.

31. The method of Claim 21, further comprising the step of:

assigning each of said one or more set-tops boxes a specific transmission slot with a slotted assignment system associated with said headend receiver, wherein each slot comprises a specific slice of time used to transmit information.

32. The method of Claim 31, further comprising the step of:

said slotted assignment system providing a guard band such that a worst case clock skew between different transmitters does not result in overlap from slot to slot.

33. The method of Claim 31, further comprising the step of:

said slotted assignment system providing a timestamp that is broadcast downstream to each of said one or more set-top boxes at a regular interval.

34. The method of Claim 32, further comprising the step of:

repeating said timestamp at regular intervals so that inherent timing inaccuracy of individual set-top boxes is not given an opportunity to become significant because each of said one or more set-top boxes resets a slot timer when it receives a broadcast time-stamp.

35. The method of Claim 33, further comprising the step of:

said headend receiver requesting that each of said one or more set-top boxes echo a specific command as rapidly as possible during system initialization, while polling each of said one or more nodes for attached set-top boxes.

36. The method of Claim 35, further comprising the steps of:

providing a mechanism running an internal timer in said headend receiver at the instant said head-end receiver sends out said command to a particular one of said one or more set-top boxes;

incrementing said timer is until a response is received from said particular one of said one or more set-top boxes;

wherein said response is an echo of said timestamp;

wherein a value of said timer is an accurate measure of propagation delay plus processing delay in said particular one of said one or more set-top boxes once a response has been received by said headend receiver; and

wherein a value is generated for each of said one or more set-top boxes to align timing for said one or more set-top boxes.

37. The method of Claim 36, further comprising the step of:

said headend receiver repeatedly operating said mechanism several times and averaging time correction results obtained thereby.

38. The method of Claim 36, further comprising the step of:

said head-end receiver transmiting a particular time correction factor it computed while polling said one or more set-top boxes back to a corresponding one of said one or more set-top boxes;

wherein said corresponding one or said one or more set-top boxes subtracts said timing correction factor from a nominal slot time to determine a corrected slot time; and

wherein a transmission packet is aligned properly to a desired slot transmission point by the time said particular one or said one or more set-top boxes actually begins transmission.

39. The method of Claim 32, said slotted assignment system further comprising:

a mechanism that enables interrupts to occur at a desired slot frequency.

40. The method of Claim 39, further comprising the steps of:

providing a timer interrupt programmed to awaken a CPU at each set-top box at a nearest hardware interrupt point preceding a desired slot interval; and

providing a counter for counting down a remaining time until said set-top box's transmission slot is reached;

wherein said slots are subdivided into sub-slots that are finer that the resolution of said set-top box.

41. A method for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said method comprising the steps of:

providing a headend receiver responsible for active frequency management of an upstream transmission RF spectrum, wherein said headend receiver is capable of simultaneously receiving data from all possible upstream channels;

wherein communication between said headend receiver and said one or more set-top boxes proceeds via a parallel transmission model over said RF spectrum which comprises a plurality of communications channels.

42. A method for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said method comprising the steps of:

assigning each of said one or more set-tops boxes a specific transmission slot with a slotted assignment system associated with a headend receiver, wherein each slot comprises a specific slice of time used to transmit information;

providing a timer interrupt programmed to awaken a CPU at each set-top box at a nearest hardware interrupt point preceding a desired slot interval; and

providing a counter for counting down a remaining time until said set-top box's transmission slot is reached;

wherein said slots are subdivided into sub-slots that are finer that the resolution of said set-top box.

43. A method for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said method comprising the steps of:

assigning each of said one or more set-top boxes to a transmission channel with a headend receiver; and

keeping track of assignments of channels by storing a mapping between each channel and a set-top box to which said channel is assigned in an allocation table associated with said headend receiver.

44. An apparatus for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said apparatus comprising:

a headend receiver responsible for active frequency management of an upstream transmission RF spectrum;

wherein said headend receiver further comprises:

a mechanism for simultaneously receiving data from all possible upstream channels; and

a parallel transmission model, wherein communication between said headend receiver and said one or more set-top boxes proceeds over said RF spectrum which comprises a plurality of communications channels.

45. An apparatus for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said apparatus comprising:

means for assigning each of said one or more set-tops boxes a specific transmission slot with a slotted assignment system associated with a headend

receiver, wherein each slot comprises a specific slice of time used to transmit information;

a timer interrupt programmed to awaken a CPU at each set-top box at a nearest hardware interrupt point preceding a desired slot interval; and

a counter for counting down a remaining time until said set-top box's transmission slot is reached;

wherein said slots are subdivided into sub-slots that are finer that a resolution of said set-top box.

46. An apparatus for increasing bandwidth in a frequency hopping transmission system comprising one or more set-top boxes, each of said set top boxes associated with a particular one of one or more nodes, said apparatus comprising:

means for assigning each of said one or more set-top boxes to a transmission channel with a headend receiver; and

an allocation table associated with said headend receiver for keeping track of assignments of channels by storing a mapping between each channel and a set-top box to which said channel is assigned.

Increased Bandwidth in Aloha-based Frequency Hopping Transmission Systems

ABSTRACT

A method and apparatus that increases bandwidth in Aloha-based frequency hopping transmission systems is disclosed. A first step in improving efficiency of known systems is to increase the number of parallel upstream transmissions by changing known systems from frequency hopping to a parallel transmission model. To increase upstream bandwidth, the first step is to replace the existing headend receiver with one that is capable of simultaneously receiving data from all of the possible upstream channels simultaneously. Next, by treating the head-end receiver and the set-top boxes as an integrated system, it is possible to use the existing transmission spectrum much more efficiently. Instead of enabling each set-top box to perform frequency hopping, it is much more effective if the head-end receiver is made responsible for active frequency management of the upstream transmission spectrum. To do this, when the system is first powered-up, the head-end receiver examines the RF spectrum to determine which frequencies are available, and which are not available due to interference from other sources. After determining which frequencies are free of interference, the headend receiver then polls the node to determine how many set-top boxes are active in this node. Once this is complete, the headend receiver partitions the set-top boxes into an approximately equal number of set-top boxes for each of the available upstream data channels. That is, the boxes are assigned a

transmission channel. The head-end receiver then commands each set-top box to tune to the channel it has been assigned by sending the channel selection information to each set-top box, *i.e.* using the separate downstream transmission channel mentioned above. A second major change to known systems revises the transmission control protocol from an Aloha system to a slotted assignment system. To do this, the head-end receiver is used not just to assign each set-top box a specific transmission channel, but also a specific transmission slot. By assigning a specific set-top box to a particular slot, it becomes possible for multiple set-top boxes to transmit in sequential slots, while assuring that the transmission packets do not collide.

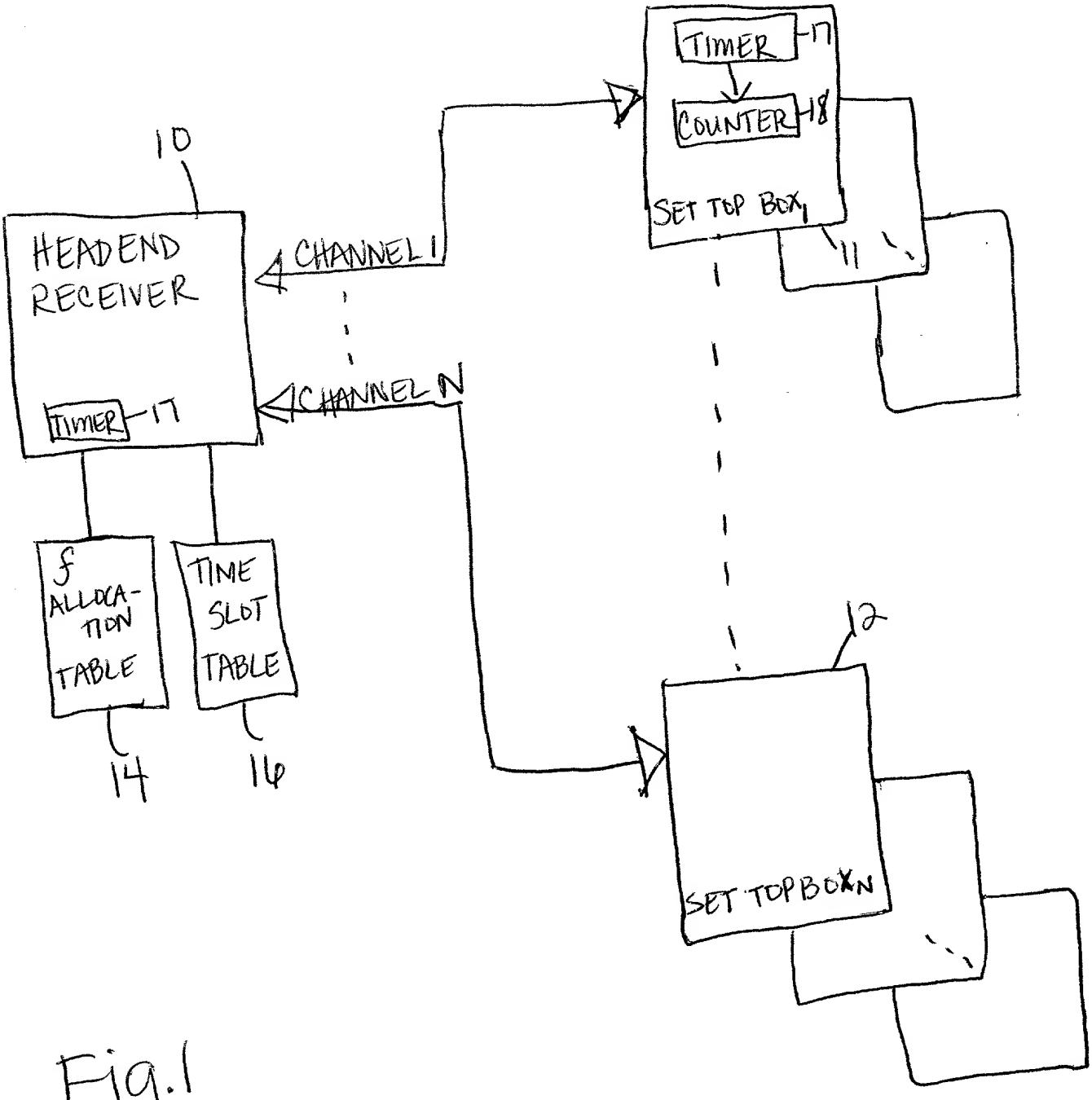
TIMER
17
COUNTER
18
SET TOP BOX 1
11
10
HEADEND RECEIVER
CHANNEL 1
CHANNEL N
TIMER
17
f ALLOCATION TABLE
TIME SLOT TABLE
14
16
12
SET TOP BOX N

Fig. 1

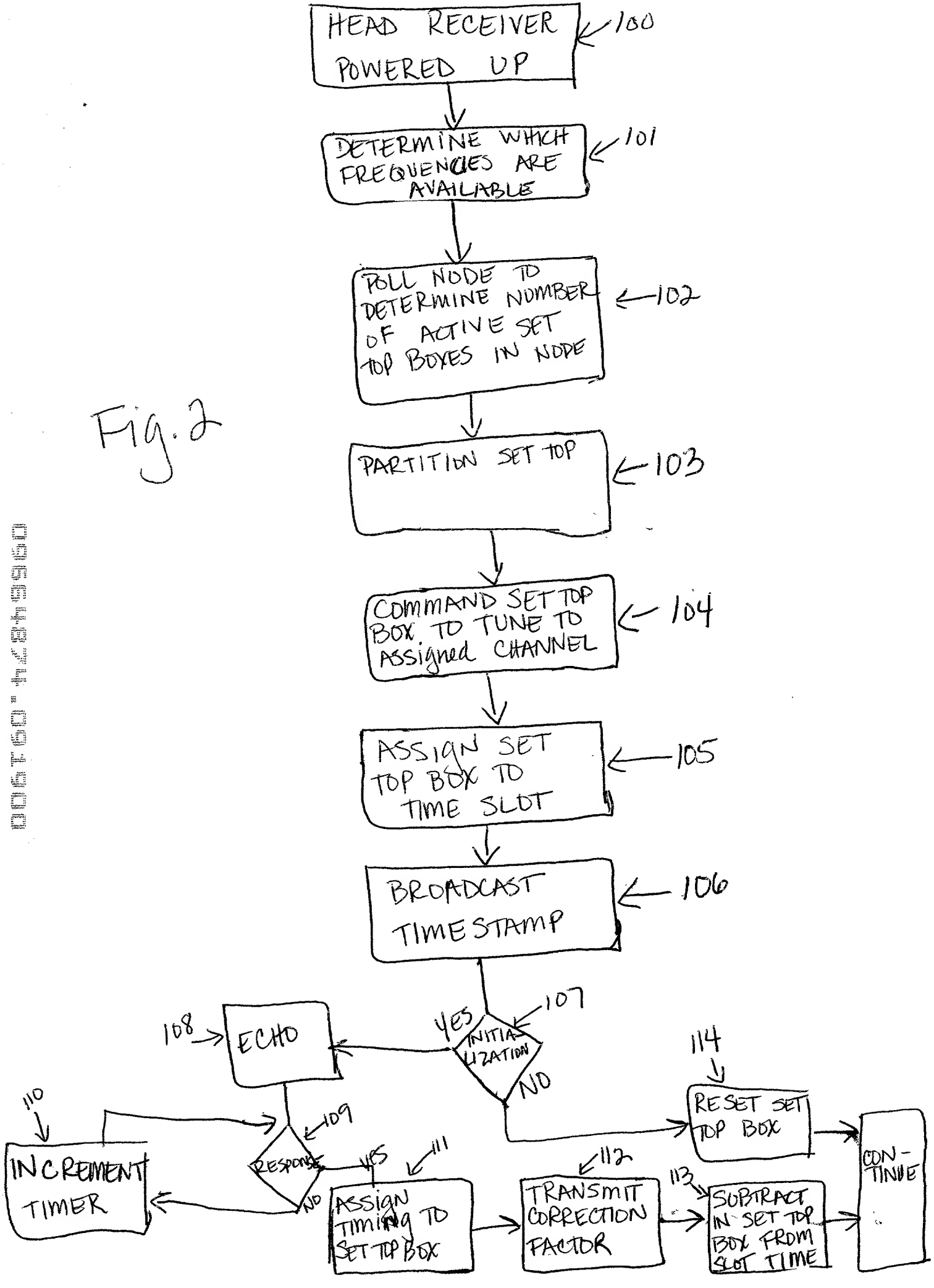
HEAD RECEIVER POWERED UP
100
DETERMINE WHICH FREQUENCIES ARE AVAILABLE
101
POLL NODE TO DETERMINE NUMBER OF ACTIVE SET TOP BOXES IN NODE
102
PARTITION SET TOP
103
COMMAND SET TOP BOX TO TUNE TO ASSIGNED CHANNEL
104
ASSIGN SET TOP BOX TO TIME SLOT
105
BROADCAST TIMESTAMP
106
INITIALIZATION
107
YES
NO
ECHO
108
RESPONSE
109
YES
NO
INCREMENT TIMER
110
ASSIGN TIMING TO SET TOP BOX
111
TRANSMIT CORRECTION FACTOR
112
SUBTRACT IN SET TOP BOX FROM SLOT TIME
113
RESET SET TOP BOX
114
CONTINUE

Fig. 2

CHANNEL	STATUS	ALLOCATION TABLE ENTRY
1	BUSY	—
2	AVAILABLE	2
.		.
.		.
.		.
N	BUSY	N-1

14

Fig. 3

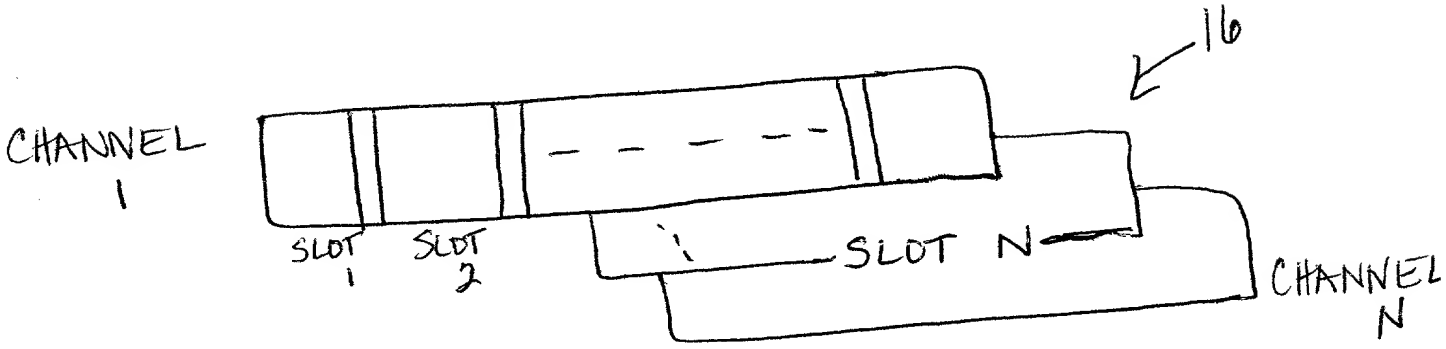

Fig. 4

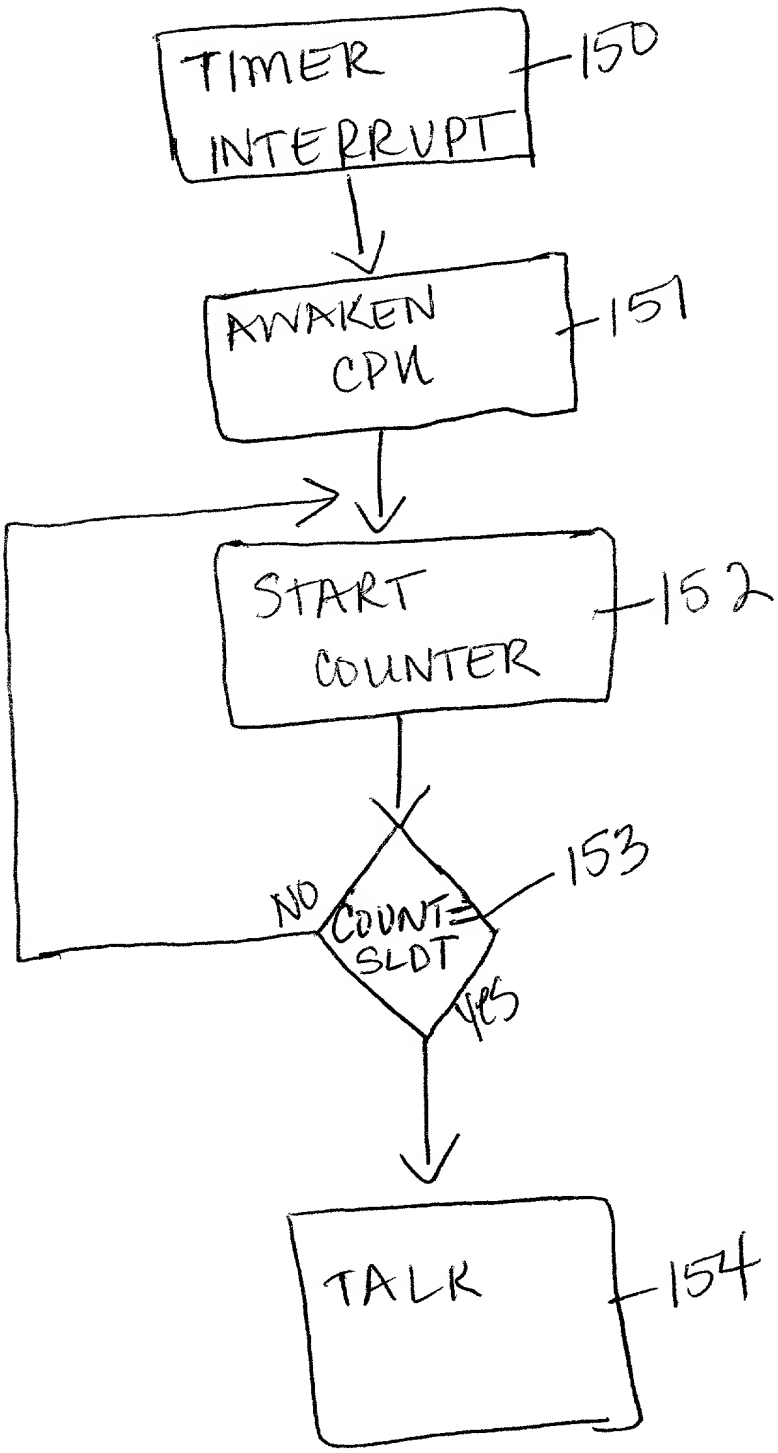
TIMER INTERRUPT
150
AWAKEN CPU
151
START COUNTER
152
NO
COUNT = SLOT
153
YES
TALK
154

Fig. 5

Attorney Docket No. AGLE0005

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name;

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

INCREASED BANDWIDTH IN ALOHA-BASED FREQUENCY HOPPING TRANSMISSION SYSTEMS

the specification of which (check one) X is attached hereto, or ___ was filed on _____ as Application Serial No. _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

==========

I hereby claim foreign priority benefits under Title 35, United Sates Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)	Priority Claimed Yes	No
_____	____	____
Number Country Day/Month/Year Filed		
_____	____	____
Number Country Day/Month/Year Filed		

==========

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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Attorney Docket No. AGLE0005

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==========

I hereby claim the benefit under Title 35, United States code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Ser. No.	Filing Date	Status: Patented, Pending, Abandoned

==========

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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